Theory of one-atom laser in a photonic band gap micro-chip

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We present a quantum theory of a coherently pumped two-level atom in a photonic band gap, coupled to both a multi-mode wave-guide channel and a high quality micro-cavity embedded within a photonic crystal. One mode is engineered to exhibit a sharp cutoff within the photonic band gap, leading to a large discontinuity in the local photon density of states near the atom, and the cavity field mode is resonant with the central component of the Mollow spectrum of atomic resonance fluorescence. Another mode of the wave-guide channel is used to propagate the pump beam. We derive analytical expressions for the optical amplitude, intensity, second order correlation functions, and conjugate quadrature variances for the light emitted by the atom into the micro-cavity. The quantum degree of second order coherence in the cavity field reveals enhanced, inversionless, nearly coherent light generation when the photon density of states jump between the Mollow spectral components is large. The cavity field characteristics are highly distinct from that of a corresponding high Q cavity in ordinary vacuum. In the case of a vanishing photon density of states on the lower Mollow sideband and no dipolar dephasing, the emitted photon statistics is Poissonian, and the cavity field exhibits quadrature coherence.

[1] L. Florescu, S. John, T. Quang and R. Wang, Physical Review A, **69**, 013816 (2004).